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VARIABLE SPEED DRIVE UNIT FOR COMPRESSOR OF HEAT PUMP

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Abstract

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(54) VARIABLE SPEED DRIVE UNIT FOR COMPRESSOR OF HEAT PUMP

(71) We, ELECTRIC POWER RESEARCH INSTITUTE, INC., a corporation organised and existing under the laws of the District of Columbia, United States of America, of 3412 Hillview Avenue, Palo Alto, California, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:–

This invention relates to drive units for compressors, for example, those forming part of a heat pump.

Conventional heat pumps currently in use have the disadvantage of experiencing a rapidly declining capacity with a decrease in ambient temperature as heat demand rises. What is needed is a way of controlling the speed of operation of the fluid compressor of such a heat pump so that this disadvantage is not experienced. It has been suggested that a practical two or three-spaced drive could be used but conventional drives of this character require servos, clutches and the like in the hermetic housing of the drive, a condition that is hardly tolerable. A suggestion has been made to use a consequent pole motor as a solution to this problem but such a motor is relatively large and expensive and is less efficient than the standard single-speed motor while being limited to a speed ratio of about 2.

In view of the foregoing, a need has arisen for an improved, efficient, variable speed drive unit for a fluid compressor of a heat pump.

A variable speed drive unit in accordance with the present invention satisfies the foregoing need and when connected to a fluid compressor, allows the compressor to be operated at any one of three speeds, namely, a low speed, an intermediate speed and a high speed. This variable speed is obtained by the use of two coaxial motors, and gear means arranged in a simple mechanical array so that the drive unit itself is readily controlled, is inexpensive to produce and operate and provides maximum efficiency notwithstanding the fact that the speeds can be changed almost immediately as the need arises.

To this end, the drive unit of this invention has two motors each motor having a rotatable drive shaft comprising: a pair of coaxial electrical motors, each motor being free of electrical connection with the other motor and having a shaft and a gear on the shaft; gear means interconnecting the gears on the shafts to permit the gears to rotate as a unit when both motors are energized; means coupled with the shaft of each motor, respectively, for preventing rotation of the shaft in one direction; and means coupled with said gear means, for coupling the same to the drive shaft of the compressor to cause the latter to rotate when one or both of the motors are energized, the motors being operable independently of each other to permit each motor to operate while the other motor is inoperable and to permit the motors to operate simultaneously, whereby the drive shaft of the compressor can be rotated at any one of the speeds.

Preferably the motors are arranged one on top of the other, with the compressor below the lower motor. One motor then has a drive shaft extending through the tubular drive shaft of the other motor, a sun gear being coupled at the lower end of the shaft of the one motor. A ring gear surrounding the sun gear is coupled to the tubular shaft, and a number of planetary gears interconnect the sun and ring gears. An arm on each planetary gear, respectively, is connected to the drive shaft of the fluid compressor, whereby operation of one or the other of the motors or both motors simultaneously permits selection of any one of three different operating speeds for the compressor shaft. This enables the compressor to meet the changing requirements of a heat pump of which the compressor forms a part. Both motors operate in a normal mode when they are actuated: thus, they do not depart substantially from their design operating conditions. Thus, conventional motors can suitably be selected to assemble the drive unit.

Such a drive unit allows operation of the compressor at any one of three speeds in an efficient manner yet the drive unit is simple and rugged in construction and inexpensive to produce and maintain.

The invention will now be further described by way of example with reference to the accompanying drawing which is a vertical

cross-section of one embodiment of drive unit and compressor in accordance with the invention.

The drive unit shown in the drawing is adapted to be used for operating a conventional fluid compressor 12 of the type having a rotatable drive shaft 14 and one or more pistons 16 coupled with shaft 14 and reciprocal in respective cylinders 18 when the shaft rotates in a predetermined direction. For purposes of illustration the compressor 12 is a two-stage structure with each piston 16 having a piston rod 20 coupled in an eccentric manner to drive shaft 14. The compressor has the usual inlet and outlet ports for receiving a fluid to be compressed and for discharging the compressed fluid, respectively. Drive shaft 14 is rotatably mounted relative to a fixed support 22 by means of a suitable bushing 24. The support 22 forms part of a casting 26 which, for purposes of illustration, houses compressor 12 as well as the drive unit. Support means of other designs can be used in place of casting 26.

The drive unit includes an upper motor 28 and a lower motor 30, the motors being coaxial with each other and with drive shaft 14 of compressor 12. Both motors can be conventional in construction and are carried in any suitable manner by casting 26 which serves as a common housing or support for the motors and the compressor.

The upper motor 28 includes a stator 32, a rotor 34 concentric to and disposed within stator 32, and a shaft 36 rigidly coupled with rotor 34 and extending downwardly therefrom.

Motor 30 includes a stator 38, a rotor 40 concentric to and disposed within stator 38, and a tubular shaft 42 rigid to rotor 40 and extending downwardly and upwardly therefrom.

Shaft 36 of motor 28 extends completely through shaft 42 of motor 30 and even extends into a recess 44 in the upper end of shaft 14 of compressor 12. A bushing 46 between shafts 14 and 36 allows relative rotation between the two shafts.

A sun gear 48 is rigidly connected to the lower end portion of the shaft 36 of motor 28 and rotates with the shaft. A number of circumferentially spaced planetary gears 50 are in mesh with sun gear 48 and are rotatable relative to and movable about the same. Each planetary gear 50 is rotatably mounted by means of a bushing 52 on a stub shaft 54 carried at the outer end of an arm 56 whose inner end is rigid to drive shaft 14 of compressor 12. Thus, each arm 56 extends radially of its planetary gear. For purposes of illustration, there are three planetary gears 50 coupled with sun gear 48, only two planetary gears 50 being shown in the figure.

Shaft 36 of motor 28 is rotatable relative to shaft 42 of motor 30. To this end, a bushing 60 is disposed between the two shafts.

A ring gear 62 is carried at the outer end of a disc 64 having a sleeve 66 rigid to the lower end of shaft 42 of motor 30. Ring gear 62 is in mesh with the planetary gears 50 and is movable relative thereto and relative to sun gear 48.

Shaft 36 is provided with a sprag 68 above motor 30 and below rotor 34 to prevent reverse rotation of the shaft when motor 30 is in operation and motor 28 is inactive. Similarly, shaft 42 is provided with a sprag 70 for the same purpose.

Electrical power is delivered to motor 28 by conductor means 72. Similarly, electrical power is delievered to motor 30 by conductor means 74. A suitable control means (not shown) permits each motor to be operated independently of the other motor, yet allows both motors to operate simultaneously.

By virtue of the structure described above, shaft 14 is driven by the rotation of arms 56 and these arms by planetary gears 50 and sun gear 48 which in turn is driven by motor 28. Motor 30 drives ring gear 62. The relative speeds of rotation of shaft 14 are one, one minus R, and R, where R is the ratio of the number of sun gear teeth to the sum of the sun gear and ring gear teeth. The high relative speed is obtained by driving both the sun and ring gears; i.e., operating both motors 28 and 30; the intermediate relative speed is obtained by driving only the ring gear, i.e., operating motor 30 alone; and the low relative speed is obtained by driving only the sun gear, i.e., operating only motor 28.

In operation, one or both motors are driven depending upon the desired speed of rotation of the shaft 14. To operate each motor, electrical power is supplied from an external power source by way of the respective conductor means.

Several advantages accrue from the use of the drive unit described. For instance, by operating at the low relative speed on mild days when the low side vapor density is highest, the total power of the two motors is much smaller than the required power of a single, single-speed motor. Moreover, the electrical efficiency of the drive unit is maximum since each of the two motors thereof operates in a normal mode and never operates very far above or below its design point. Also, mechanical and hydraulic efficiencies are maximised by speed reduction.

The sun and planetary gears do not roll at high speed but turn as a unit, so that even the gear loss associated with these gears is substantially absent in very cold weather operation. Speeds can be changed instantaneously which is by way of external relay means coupled to the conductor means of the two motors. The cost of drive unit 10 is less than that of any competitive speed changer,

given that a low cost gear set is developed since the copper and iron total is less than that of a single motor.

WHAT WE CLAIM IS:—

1. A drive unit for a fluid compressor having a rotatable drive shaft comprising: a pair of coaxial electrical motors, each motor being free of electrical connection with the other motor and having a shaft and a gear on the shaft; gear means interconnecting the gears on the shafts to permit the gears to rotate as a unit when both motors are energized; means coupled with the shaft of each motor, respectively, for preventing rotation of the shaft in one direction; and means coupled with said gear means for coupling the same to the drive shaft of the compressor to cause the latter to rotate when one or both of the motors are energized, the motors being operable independently of each other to permit each motor to operate while the other motor is inoperable and to permit the motors to operate simultaneously, whereby the drive shaft of the compressor can be rotated at any one of three speeds.

2. A drive unit as claimed in Claim 1, wherein the shaft of one of the motors is tubular, the shaft of the other motor being rotatably received within the shaft of said one motor.

3. A drive shaft as claimed in either Claim 1 or 2 wherein one of the gears is a ring gear and the other gear is a sun gear spaced inwardly from and concentric with the ring gear.

4. A drive unit as claimed in any of the preceding claims, wherein the gear means includes a number of planetary gears in mesh with the gears on the shafts.

5. A drive unit as claimed in Claim 4, wherein each planetary gear has an arm connected to the centre thereof and extending radially outwardly therefrom, the outer end of each arm being adapted to be secured to the drive shaft of the compressor.

6. A drive unit as claimed in Claim 1, wherein one of the motors is positioned above the other motor and the said other motor is positioned above the compressor, the said other motor having a tubular shaft and the said one motor having its output shaft extending through the tubular shaft and provided with a sun gear on the normally lowermost end thereof, the tubular shaft having a ring gear thereon in surrounding, spaced relationship to the sun gear, there being a number of planetary gears in mesh with the sun and ring gears, each planetary gear having an arm mounted thereon at the centre thereof and extending radially therefrom, the outer end of each arm being adapted to be coupled to the drive shaft of the compressor.

7. The combination of a fluid compressor having a rotatable drive shaft and a drive unit as claimed in any of Claims 1 to 6 the pair of electrical motors being coaxial with the compressor.

8. A compressor and drive unit as claimed in Claim 7, having a common housing for the compressor and the motors, the compressor being positioned below the motors, one of the motors being above the other motor.

9. A drive unit substantially as hereinbefore described with reference to the accompanying drawing.

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1579045 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*